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DATA SHEET

SAA1504T
Safety IC

Objective specification
File under Integrated Circuits, IC17

2000 Mar 07

Philips
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Safety IC SAA1504T

FEATURES

- Zero voltage start-up
- Discharge and charge overcurrent protection
- Automatic release of current protection at removal of charger or load
- Low current consumption in normal operating mode
- Very low current consumption when battery voltage is lower than 2.3 V
- Accurate voltage detection levels
- Continuous monitoring of battery voltage and charge or discharge current
- External power FETs are driven with an elevated supply voltage, reducing the on-resistance
- Able to accommodate 20 V charge voltage
- Read out of charge (disable) status
- Small package (SO8)
- Low external components count
- Temperature protection
- Charger reverse connection protection.

GENERAL DESCRIPTION

The SAA1504T is manufactured in a BCD Power Logic 70 process and is intended to be used as a protection circuit for single cell Li-ion battery packs. The current and voltage ratings are especially designed for use in battery packs for portable telephones such as GSM.

The circuit continuously monitors the battery voltage, current and junction temperature and will disconnect the battery in case of an overload situation:

- Overdischarge protection prevents deep discharge of the cell; deep discharge of a Li-ion cell degrades the life cycle
- Overcharge protection for safety reasons
- Overcurrent protection on charge or discharge current rate
- Temperature protection for preventing charge or discharge at high temperatures
- Short circuit protection.

It must be stated that this is a safety IC to be integrated inside a battery pack. It is not primarily intended as an end of charge provision.

ORDERING INFORMATION

TYPE NUMBER	PACKAGE		
	NAME	DESCRIPTION	VERSION
SAA1504T	SO8	plastic small outline package; 8 leads; body width 3.9 mm	SOT96-1

BLOCK DIAGRAM

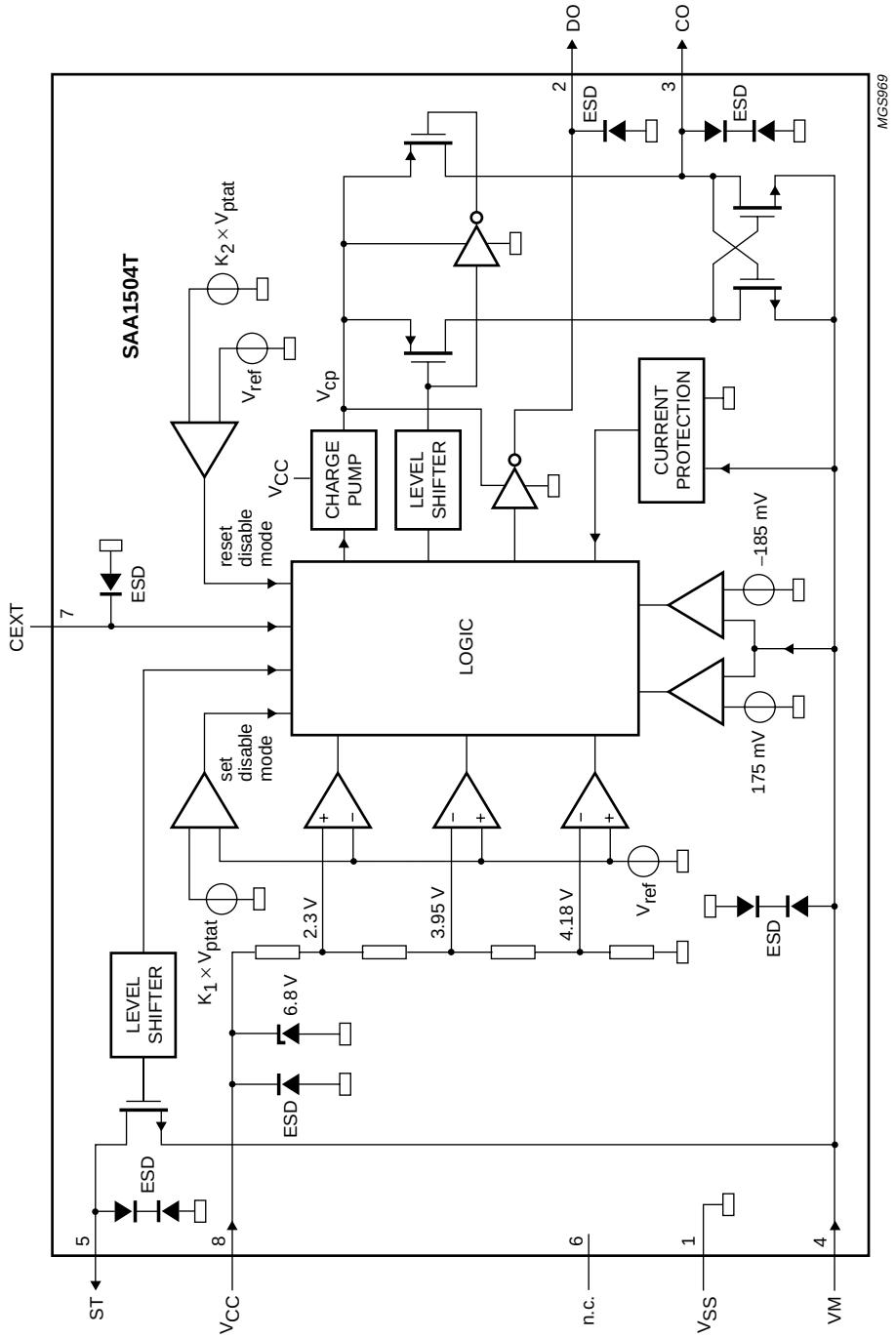


Fig.1 Block diagram.

PINNING

SYMBOL	PIN	DESCRIPTION
V_{SS}	1	ground supply
DO	2	output to gate of discharge power FET
CO	3	output to gate of charge power FET
VM	4	negative sense input
ST	5	status output
n.c.	6	not connected
CEXT	7	connection for external delay capacitor
V_{CC}	8	positive battery sense input

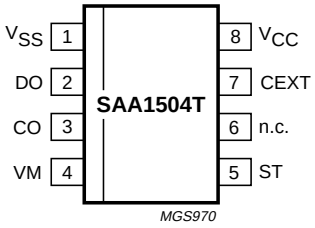


Fig.2 Pin configuration.

FUNCTIONAL DESCRIPTION

The basic function of the SAA1504T is to protect a single Li-ion cell against overcharge and overdischarge for reasons of life time and safety. The voltage across the cell terminals (V_{bat}) is monitored continuously and compared to an accurate internal reference voltage.

The circuit diagram (see Fig.3) of a Li-ion battery pack shows the SAA1504T and 2 power NMOS transistors which are connected in anti series. Both transistors must have their backgate connected to their source, resulting in 2 backgate diodes in anti series.

The timing diagram (see Fig.6) shows the detection levels for the various modes of operation.

Battery voltage between 2.6 and 4.18 V

The safety IC is in the normal operating mode for V_{bat} = 2.6 to 4.18 V, a charge or discharge current below the current-protection level and a junction temperature below the temperature protection activation level. In this mode transistors SW1 and SW2 are driven with an elevated supply voltage (with a charge pump) which guarantees a low on-resistance in the main current path. This is important for fully utilizing the high energy density of the Li-ion battery technology.

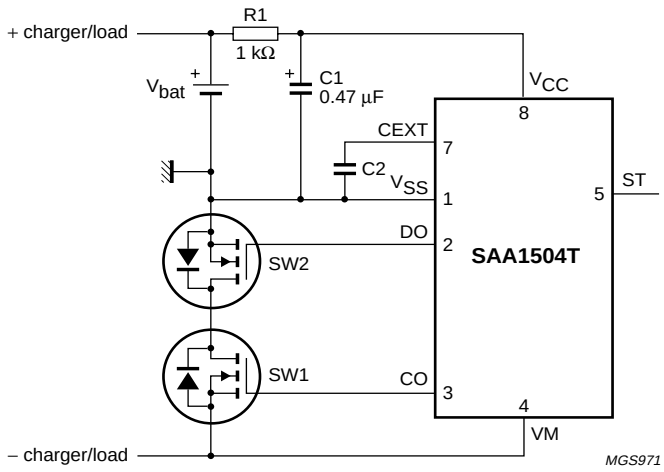


Fig.3 Safety IC connection diagram.

Battery voltage below 2.3 V

When V_{bat} < 2.3 V the safety IC is in the Power-down mode: SW2 is open to block a further discharge.

The battery voltage will increase stepwise, because of the sudden disconnection of the load. The safety IC will not re-enter the normal operating mode at this event unless the battery voltage exceeds the power-down release level of 2.6 V and a charge current is present. So when no charger is present in the Power-down mode, the safety IC stays in this mode, independent of the battery voltage.

Connecting a charger in the Power-down mode is detected by a negative voltage on pin VM. Because the voltage at pin VM is defined by a charge current via the backgate diode of SW2, a charge current of a few nAs is already detected. When a charge current is detected and V_{bat} > 2.6 V, the system will go from the Power-down mode to the normal operating mode.

In the Power-down mode the supply current is reduced to 150 nA (typical value) for minimizing the discharge of the battery by the safety IC. This is achieved by disabling all analog circuitry, except the circuitry for detecting the presence of a charger and for detecting V_{bat} > 2.6 V. Because the charge pump is disabled and battery charging should be possible, SW1 is switched on with a reduced V_{gs} voltage.

Battery voltage above 4.18 V

When the battery is charged to V_{bat} > 4.18 V, the safety IC will enter the charge inhibit mode: SW1 is open and charging is disabled.

Connecting a load in the charge inhibit mode is detected by the reversal of the voltage across SW1 and will immediately close SW1, so entering the discharge enable mode. A short time is needed to charge the gate of SW1. During this time the backgate diode between drain and source of SW1 conducts.

The safety IC will remain in the discharge enable mode unless:

- V_{bat} < 3.95 V, which results in re-entering the normal operating mode. This transition is not externally noticeable, because both switches remain closed.
- A charger is connected, which will immediately open SW1. As an additional safety precaution V_{bat} > 4.18 V also yields the same reaction, because otherwise a small current of a charger may be undetected, leading to overcharging the Li-ion cell.

Zero voltage start-up

The safety IC has to be able to charge the battery at 0 V. This means that when connecting a charger in case of a completely empty battery, SW1 has to be open.

In the Power-down mode output CO is connected via a diode to V_{CC}, so that the charge transistor will be active when V_{VM} is negative.

Maximum charge or discharge current and temperature protection

When the maximum charge or discharge current is exceeded or when the maximum temperature is detected the disable mode is activated and will open both switches. Exceeding the maximum charge or discharge current is detected by a voltage drop or rise on pin VM when both switches are closed.

A release of this mode can only be achieved by removing the load (or charger) and at a junction temperature below 60 °C. The disable mode is followed by a return to its previous mode.

Normal operating mode

In case of correct temperature, battery voltage and charge or discharge current, the system will be in the normal operating mode (see Fig.4).

Both the charge and discharge outputs will be HIGH (CO = 1 and DO = 1), so both switches are closed.

Power-down mode

When V_{bat} < 2.3 V the safety IC will enter the Power-down mode (see Fig.4). The power-down detection level of 2.3 V has a delay of 5 ms (typical value). The Power-down mode will also be entered without delay when V_{bat} < 1.9 V.

In this mode only charging of the battery is allowed (CO = 1 and DO = 0).

The safety IC will return to the normal operating mode as soon as V_{bat} > 2.6 V and a charge current is detected at the same time.

Charge inhibit mode

When V_{bat} > 4.18 V, the charge inhibit mode will be entered (see Fig.4). At this mode the battery can only be discharged (CO = 0 and DO = 1).

The excess charge delay can be set by means of an external capacitor. The delay is then defined as: $t_{ed(det)} = 30 \times C_{CEXT}$ with $t_{ed(det)}$ in ms and C_{CEXT} in nF.

When V_{bat} < 3.95 V, the safety IC will return from the charge inhibit mode to the normal operating mode.

The charge inhibit mode will also be entered as soon as a charge current is detected in the discharge enable mode

Discharge enable mode

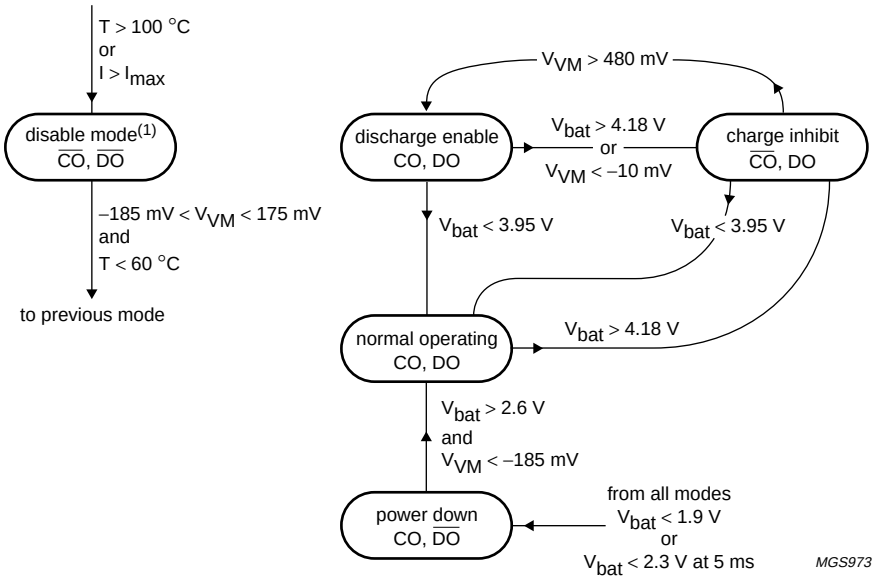
When the safety IC is in the charge inhibit mode, charging of the battery is disabled because SW1 is open. Initially discharge of the battery will then occur via the backgate diode of SW1. The load voltage will be approximately 0.6 V lower and dissipation of the backgate diode of SW1 will occur. It is preferable to close both switches at that time without allowing charging of the battery until V_{bat} < 3.95 V.

If a discharge current is detected in the charge inhibit mode, the system will activate the discharge enable mode, closing both switches.

From the discharge enable mode the charge inhibit mode will be entered again as soon as a charge current is detected or V_{bat} > 4.18 V. The detection of a higher voltage than 4.18 V is necessary. If the battery is charged with a very low charge current, the safety IC will not switch from the discharge enable mode to the charge inhibit mode. Eventually, the safety IC will enter the charge inhibit mode if the battery is overcharged to V_{bat} > 4.18 V because of a small charge current.

When V_{bat} < 3.95 V the safety IC will return from the discharge enable to the normal operating mode.

If the safety IC is in the charge inhibit mode, it will usually go to the normal operating mode via the discharge enable mode. But if the system is in the charge inhibit mode and the battery pack is stored for several years, the battery voltage can drop because of the battery discharge by the safety IC and the self discharge of the battery. So a voltage drop of the battery is possible, without detecting a discharge current. Because of this, the normal operating mode should also be entered from the charge inhibit mode when V_{bat} < 3.95 V and not only from the discharge enable mode. In this way, charging a battery is always possible if V_{bat} < 3.95 V.



(1) Minimum time in the disable mode is about 5 ms.

Fig.4 Flow diagram.

Disable mode

When the charge or discharge current exceeds the specified maximum value, the disable mode is entered. Detection of the maximum charge or discharge current is only activated when the outputs are HIGH (CO = 1 and DO = 1) as explained next.

If the safety IC is in the Power-down mode and a charge current is detected (e.g. V_{VM} = –0.6 V) the normal operating mode will be entered when V_{bat} > 2.6 V. Because of a minimum time in which the gate capacitors have to be charged, V_{VM} = –0.6 V for a small period, when the safety IC is already in the normal operating mode. V_{VM} = –0.6 V could also occur when the battery is charged with a current exceeding the maximum charge current. To prevent that a maximum charge current is detected when coming from the Power-down mode a delay is included to ensure charging of both outputs CO and DO. So entering of the disable mode is enabled when both outputs CO and DO are fully charged or after a certain delay. The delay is necessary to activate the current protection even in case the outputs CO or DO can not be fully charged.

The same applies for entering the disable mode when the safety IC is in the discharge enable mode.

The delay of the current protection as a function of the sense voltage V_{VM} (for charge and discharge) is given in Fig.5.

The disable mode is also entered when the junction temperature exceeds 100 °C. When the temperature drops below 60 °C and at the absence of a charger or load, the safety IC will return to its previous mode.

Status output

The status of the safety IC is available on pin ST.

Table 1 Functional table of the status output

MODE	OUTPUT PIN ST
Normal operating	LOW
Charge inhibit	HIGH
Discharge enable	LOW
Power-down	LOW
Disable	HIGH (note 1)

Note

1. Only when a charger is connected.

LIMITING VALUES

In accordance with the Absolute Maximum Rating System (IEC 60134); voltages measured with respect to pin V_{SS}.

SYMBOL	PARAMETER	CONDITION	MIN.	MAX.	UNIT
V_{CC}	positive battery sense input voltage	DC constant	–0.3	+4.5	V
$V_{CC(clamp)}$	clamping voltage	$I_{CC(clamp)}$ = 7 mA; t < 60 ms	–	8.5	V
$I_{CC(clamp)}$	clamping current		–	7	mA
V_{rev}	reverse charger voltage	$V_{rev} = -(V_{CC} - V_{VM})$; V_{VM} positive with respect to V_{CC}	–	20	V
V_{VM}	negative sense input voltage		V_{CC} – 20	V_{CC} + 20	V
V_{ST}	voltage on pin ST		V_{VM}	V_{CC}	V
T_{amb}	ambient temperature		–25	+80	°C
T_{stg}	storage temperature		–55	+150	°C

THERMAL CHARACTERISTICS

SYMBOL	PARAMETER	CONDITIONS	VALUE	UNIT
$R_{th(j-a)}$	thermal resistance from junction to ambient	in free air	160	K/W

QUALITY SPECIFICATION

In accordance with *"SNW-FQ-611-D"* and JEDEC class III.

CHARACTERISTICS

T_{amb} = 25 °C; voltages measured with respect to pin V_{SS}; unless otherwise specified.

SYMBOL	PARAMETER	CONDITIONS	MIN.	TYP.	MAX.	UNIT
Supply behaviour						
V_{CC}	positive battery sense input voltage		0	–	4.5	V
I_{CC}	supply current	V_{CC} = 4.0 V; V_{VM} = 0 V	7.0	9.0	11	µA
I_q	quiescent supply current	Power-down mode				
		V_{CC} = 2.0 V	75	150	300	nA
		V_{CC} = 1.5 V	35	75	150	nA
$V_{CC} - V_{VM}$	minimum charge voltage	at zero charge current; V_{CC} = 0 V	1.8	2.4	3.0	V
Detection levels of V_{bat}; note 1						
$V_{ec(det)}$	excess charge detection voltage	T_j = 25 °C	4.155	4.18	4.205	V
		T_j = –10 to +60 °C	4.150	4.18	4.210	V
$t_{ec(det)}$	excess charge detection voltage delay	C_{CEXT} = 33 nF ±10%	0.4	1	2	s
$V_{ec(rel)}$	excess charge release voltage		3.87	3.95	4.03	V
$V_{pd(rel)}$	power-down release voltage		2.35	2.6	2.85	V
$V_{pd(det)}$	power-down detection voltage		2.25	2.3	2.35	V
$t_{pd(det)}$	power-down detection voltage delay		1	5	17	ms
$V_{pd(min)}$	power-down minimum voltage		1.6	1.9	2.2	V
Detection levels on pin VM						
$V_{dch(det)}$	discharge detection voltage	charge inhibit mode	450	480	510	mV
$V_{ch(det)}$	charge detection voltage	discharge enable mode	–5	–10	–20	mV
$V_{ch(pres)}$	charger present voltage	Power-down or disable mode	–120	–185	–250	mV
$V_{l(pres)}$	load present voltage	disable mode	145	175	205	mV
I_{VM}	current at pin VM	$V_{CC} - V_{VM}$ = 15 V; V_{CC} = 4.33 V	1	2	3	µA
Outputs on pins CO and DO						
V_{OH}	HIGH-level output voltage	V_{CC} = 2.4 V; R_L = ∞	4.4	4.6	4.8	V
		V_{CC} = 4.0 V; R_L = ∞	6.4	7	7.6	V
Temperature protection						
$T_{prot(start)}$	start of temperature protection	disable mode	90	100	110	°C
$T_{prot(rel)}$	release of temperature protection		50	60	70	°C
Current protection; see Fig.5; note 2						
$V_{prot(min)}$	minimum current-protection voltage	DC level on pin VM	150	250	350	mV
t_d	delay	minimum value	100	200	400	µs
		at V_{VM} = 510 mV	2	4	8	ms

SYMBOL	PARAMETER	CONDITIONS	MIN.	TYP.	MAX.	UNIT
Status output on pin ST						
I_O	output current	pin ST = HIGH; see Table 1; $V_{ST} = V_{VM} + 0.5$ V				
		$V_{CC} - V_{VM} = 20$ V	13	17	21	μA
		$V_{CC} - V_{VM} = 4$ V	9	12	15	μA

Notes

1. The voltages are measured at the terminals of the battery. This voltage equals the voltage across series resistor R1 = 1 kΩ plus the voltage on pin V_{CC} (see Fig.3).
2. For both charge and discharge state.

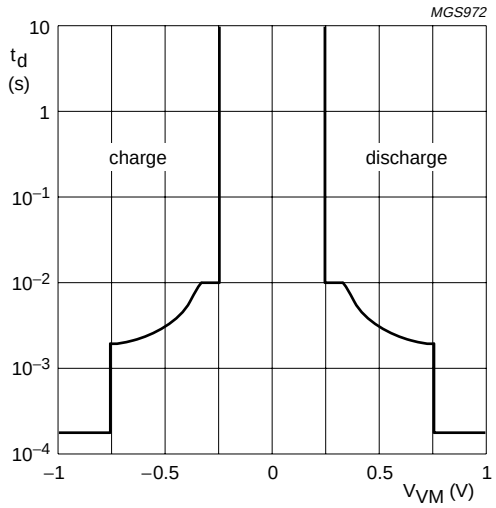


Fig.5 Current-protection delay.

TIMING DIAGRAM

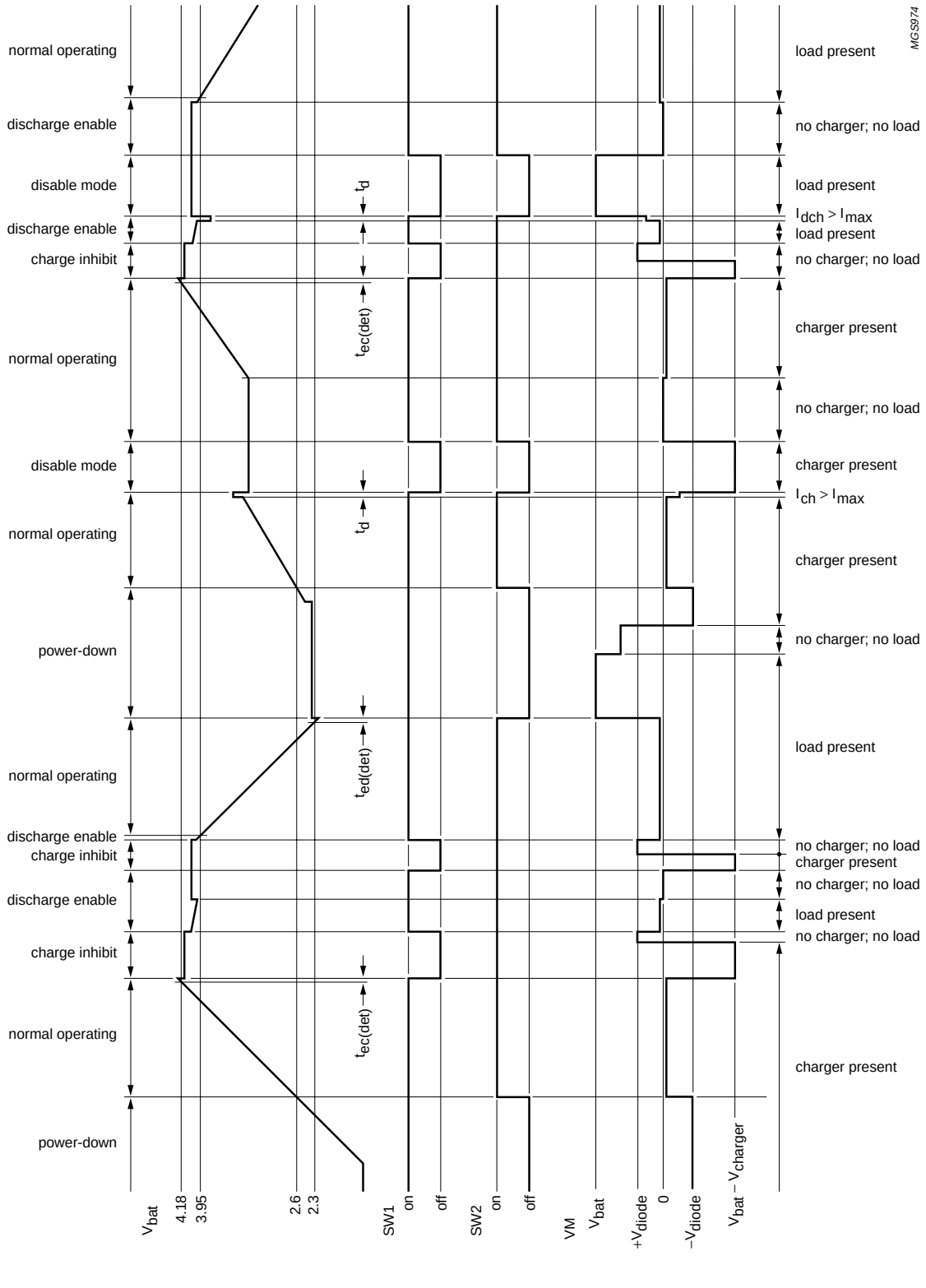
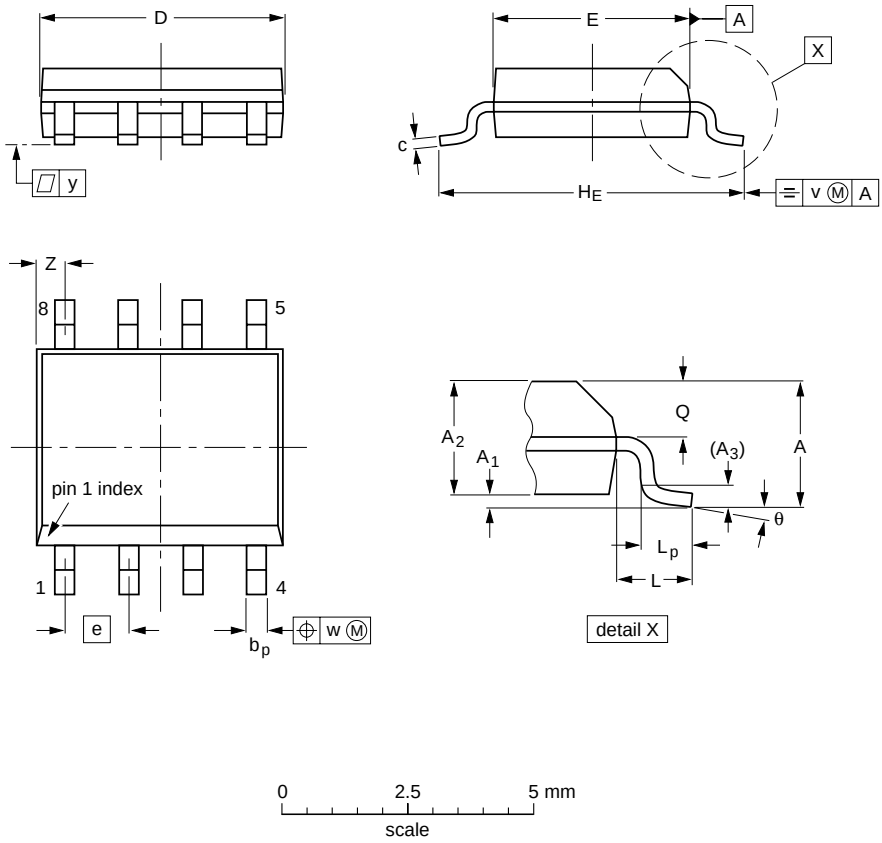


Fig.6 Timing diagram.

PACKAGE OUTLINE

SO8: plastic small outline package; 8 leads; body width 3.9 mm **SOT96-1**



DIMENSIONS (inch dimensions are derived from the original mm dimensions)

UNIT	A max.	A_1	A_2	A_3	b_p	c	$D^{(1)}$	$E^{(2)}$	e	H_E	L	L_p	Q	v	w	y	$Z^{(1)}$	θ
mm	1.75	0.25 0.10	1.45 1.25	0.25	0.49 0.36	0.25 0.19	5.0 4.8	4.0 3.8	1.27	6.2 5.8	1.05	1.0 0.4	0.7 0.6	0.25	0.25	0.1	0.7 0.3	8^o 0^o
inches	0.069	0.010 0.004	0.057 0.049	0.01	0.019 0.014	0.0100 0.0075	0.20 0.19	0.16 0.15	0.050	0.244 0.228	0.041	0.039 0.016	0.028 0.024	0.01	0.01	0.004	0.028 0.012	

Notes

1. Plastic or metal protrusions of 0.15 mm maximum per side are not included.
2. Plastic or metal protrusions of 0.25 mm maximum per side are not included.

OUTLINE VERSION	REFERENCES				EUROPEAN PROJECTION	ISSUE DATE
	IEC	JEDEC	EIAJ			
SOT96-1	076E03	MS-012				~~97-05-22~~ 99-12-27

SOLDERING

Introduction to soldering surface mount packages

This text gives a very brief insight to a complex technology. A more in-depth account of soldering ICs can be found in our *"Data Handbook IC26; Integrated Circuit Packages"* (document order number 9398 652 90011).

There is no soldering method that is ideal for all surface mount IC packages. Wave soldering is not always suitable for surface mount ICs, or for printed-circuit boards with high population densities. In these situations reflow soldering is often used.

Reflow soldering

Reflow soldering requires solder paste (a suspension of fine solder particles, flux and binding agent) to be applied to the printed-circuit board by screen printing, stencilling or pressure-syringe dispensing before package placement.

Several methods exist for reflowing; for example, infrared/convection heating in a conveyor type oven. Throughput times (preheating, soldering and cooling) vary between 100 and 200 seconds depending on heating method.

Typical reflow peak temperatures range from 215 to 250 °C. The top-surface temperature of the packages should preferable be kept below 230 °C.

Wave soldering

Conventional single wave soldering is not recommended for surface mount devices (SMDs) or printed-circuit boards with a high component density, as solder bridging and non-wetting can present major problems.

To overcome these problems the double-wave soldering method was specifically developed.

If wave soldering is used the following conditions must be observed for optimal results:

- Use a double-wave soldering method comprising a turbulent wave with high upward pressure followed by a smooth laminar wave.
- For packages with leads on two sides and a pitch (e):
  - larger than or equal to 1.27 mm, the footprint longitudinal axis is **preferred** to be parallel to the transport direction of the printed-circuit board;
  - smaller than 1.27 mm, the footprint longitudinal axis **must** be parallel to the transport direction of the printed-circuit board.

  The footprint must incorporate solder thieves at the downstream end.
- For packages with leads on four sides, the footprint must be placed at a 45° angle to the transport direction of the printed-circuit board. The footprint must incorporate solder thieves downstream and at the side corners.

During placement and before soldering, the package must be fixed with a droplet of adhesive. The adhesive can be applied by screen printing, pin transfer or syringe dispensing. The package can be soldered after the adhesive is cured.

Typical dwell time is 4 seconds at 250 °C.
A mildly-activated flux will eliminate the need for removal of corrosive residues in most applications.

Manual soldering

Fix the component by first soldering two diagonally-opposite end leads. Use a low voltage (24 V or less) soldering iron applied to the flat part of the lead. Contact time must be limited to 10 seconds at up to 300 °C.

When using a dedicated tool, all other leads can be soldered in one operation within 2 to 5 seconds between 270 and 320 °C.

Suitability of surface mount IC packages for wave and reflow soldering methods

PACKAGE	SOLDERING METHOD	
	WAVE	REFLOW(1)
BGA, LFBGA, SQFP, TFBGA	not suitable	suitable
HBCC, HLQFP, HSQFP, HSOP, HTQFP, HTSSOP, SMS	not suitable(2)	suitable
PLCC(3), SO, SOJ	suitable	suitable
LQFP, QFP, TQFP	not recommended(3)(4)	suitable
SSOP, TSSOP, VSO	not recommended(5)	suitable

Notes

1. All surface mount (SMD) packages are moisture sensitive. Depending upon the moisture content, the maximum temperature (with respect to time) and body size of the package, there is a risk that internal or external package cracks may occur due to vaporization of the moisture in them (the so called popcorn effect). For details, refer to the Drypack information in the *"Data Handbook IC26; Integrated Circuit Packages; Section: Packing Methods"*.
2. These packages are not suitable for wave soldering as a solder joint between the printed-circuit board and heatsink (at bottom version) can not be achieved, and as solder may stick to the heatsink (on top version).
3. If wave soldering is considered, then the package must be placed at a 45° angle to the solder wave direction. The package footprint must incorporate solder thieves downstream and at the side corners.
4. Wave soldering is only suitable for LQFP, TQFP and QFP packages with a pitch (e) equal to or larger than 0.8 mm; it is definitely not suitable for packages with a pitch (e) equal to or smaller than 0.65 mm.
5. Wave soldering is only suitable for SSOP and TSSOP packages with a pitch (e) equal to or larger than 0.65 mm; it is definitely not suitable for packages with a pitch (e) equal to or smaller than 0.5 mm.

DEFINITIONS

Data sheet status	
Objective specification	This data sheet contains target or goal specifications for product development.
Preliminary specification	This data sheet contains preliminary data; supplementary data may be published later.
Product specification	This data sheet contains final product specifications.
Limiting values	
Limiting values given are in accordance with the Absolute Maximum Rating System (IEC 60134). Stress above one or more of the limiting values may cause permanent damage to the device. These are stress ratings only and operation of the device at these or at any other conditions above those given in the Characteristics sections of the specification is not implied. Exposure to limiting values for extended periods may affect device reliability.	
Application information	
Where application information is given, it is advisory and does not form part of the specification.	

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These products are not designed for use in life support appliances, devices, or systems where malfunction of these products can reasonably be expected to result in personal injury. Philips customers using or selling these products for use in such applications do so at their own risk and agree to fully indemnify Philips for any damages resulting from such improper use or sale.

NOTES

NOTES

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Printed in The Netherlands 403506/25/01/pp16 Date of release: 2000 Mar 07 Document order number: 9397 750 06537

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